Aqua Validation Investigation Report, February 2003

Project Title: **Validation of AMSR-E Antarctic Sea-Ice Products in East Antarctica, Late Winter-Early Spring 2003**.

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PRIMARY OBJECTIVES

The primary objective of this project is to conduct a field campaign onboard the Australian icebreaker R/V *Aurora Australis* in the East Antarctic seasonal sea-ice zone to validate routine AMSR-E sea-ice geophysical products i.e. concentration, snowcover thickness, and sea-ice physical temperature, in the late-austral winter to early-spring period. Data collected will be used to establish statistical relationships between the AMSR-E-derived sea-ice parameters and the same parameters derived from the other (independent) data sets. The aim is to cover as many different sea-ice regimes as possible, in order to understand the limitations of each algorithm under a range of conditions. The approach for meeting the validation objectives is one of compiling and analyzing spatially and temporally coincident data sets for comparison with the AMSR-E sea ice parameters. The strategy is to obtain a combination of spatially and temporally coincident surface, helicopter, and satellite observations to provide the requisite data needed to meet the validation objectives for the sea-ice concentration, snowcover thickness and ice-surface temperature products. Another key element is the utilization of modeling and sensitivity studies.

Secondary objectives are to validate:

- Ice Motion from AMSR-E and active microwave satellite data, using an array of buoys;
- Ocean/ice/snow skin surface temperature, using thermal IR radiometers on the ship;
- Floe size distribution, using helicopter digital areal photos extended areally and temporally by high-resolution satellite imagery (e.g. from Landsat, Ikonos/Quickbird, ASTER, and GLI);
- The satellite passive-microwave ice regime classification scheme of *Massom et al*. (1998);
- MODIS sea-ice data products;
- The polynya “size” algorithm of Dr Thorsten Markus (NASA GSFC); and
- Albedo (AVHRR Pathfinder and MODIS products), using spectral radiometers.

SUMMARY OF PROGRESS IN 2002/3, AND ACCOMPLISHMENTS TO DATE

We are currently organising an intensive multi-national campaign of *in situ* and helicopter measurements over a 17-day period in September-October 2003. The experiment will take place onboard the Australian icebreaker R/V *Aurora Australis*, which will sail from Hobart in Tasmania (Australia) to the Antarctic seasonal sea-ice zone north of the French base Dumont d’Urville.

N.B. this experiment was originally planned for 2002, but was postponed for one year as it was decided that the original date was too close to the launch of Aqua. As such, no validation has taken place so far, although a radar to measure snow thickness has been developed for testing on the 2003 cruise.

Snow Thickness Radar

Work on the development of a radar to measure snow thickness over sea ice has proceeded in collaboration with the University of Kansas (Prof. Prasad Gogineni and colleagues). This radar will be tested (as a proof-of-concept) on the sea-ice surface in Antarctica during the remote sensing validation experiment in September and October, 2003. The following year, we plan to design and construct antennae to allow the system to be operated from aircraft and further assist with the validation of the ASMR-E snow thickness algorithm.

Profiles of typical snow properties have been constructed and modelled to determine the optimal frequency range. These snow profiles include different densities, grain sizes and snow layer thickness. An ultra-wideband radar has been designed to operate over a frequency range from 2-8 GHz in FM-CW mode. Researchers at the University of Kansas have constructed the radar and tested it over a layer of foam on top of concrete. The system could successfully identify a 10-cm layer of foam. The higher dielectric constant of snow is expected to improve the overall performance. Design of a sled and the associated antenna system has begun and construction of the total sled-based system will be completed prior to the validation experiment in September, 2003. The system will be used to estimate the snow thickness over Antarctic sea ice, and the results will be used to optimise the radar parameters.

PLANS FOR THE COMING YEAR

As stated above, the field phase of the validation will now occur over a 17-day period in September-October 2003. Current cruise timing details are available on the Australian Antarctic Division website at:
http://www-old.aad.gov.au/goingsouth/schedules/0304_ship_sked.asp
Please note that the validation cruise is called Voyage 1 of the *Aurora Australis* 2003/4.

The original plan was to access the Mertz Glacier Polynya to the east (centred on ~67ºS, 145ºE). New time constraints due to a shortening of the validation phase of the cruise (from 30 to 17 days) have, however, forced us to re-evaluate our options and choose a new study region that is logistically more convenient. We have chosen the area of East Antarctic pack ice to the north of Dumont d'Urville base (at ~140ºE, Figure 1), because it contains a range of ice-type regimes, is unlikely to have prohibitively heavy ice conditions, and is logistical convenient to Hobart, Tasmania.

Figure 1. The study region for the September-October 2003 Australian field experiment.

This East Antarctic effort will complement the near-contemporaneous sea-ice validation programme in W. Antarctica of Dr Comiso (NASA GSFC), and the Arctic programme of Dr Maslanik *et al*. (Univ. of Colorado). Links to both projects are available through Drs Comiso and Cavalieri (NASA GSFC), and coordination is underway to standardize data collection techniques and protocols, in order to facilitate data inter-comparison. Another important link is provided by the participation of Dr Thorsten Markus (NASA GSFC).

Participating Institutions.

The successful completion of this experiment will depend on collaborative work by scientists from a range of institutions, including:

- Antarctic Cooperative Research Centre, Tasmania;
- Australian Antarctic Division;
- Geology Department, University of Tasmania;
- National Snow and Ice Data Center, Univ. of Colorado, USA;
- Oceans and Ice Branch, NASA GSFC, USA;
- Radar Systems and Remote Sensing Laboratory, Univ. of Kansas;
- Alfred-Wegener-Institut, Germany;
- Australian Bureau of Meteorology;
- US Naval Research Lab; and
- Université Libre de Bruxelles, Belgium.

Moreover, and as stated before, close coordination and collaboration with NASA, ESA and NASDA, and other scientists involved in the validation efforts for EOS and other satellites, is a key element.

Data Collection Strategy

Within the sea-ice zone, measurements will take place within the framework of a 75 x 100km grid pattern based initially on the locations of AMSR-E 12.5 and 25 km data product pixels, tracked by buoys for the duration of the experiment to account for ice drift. Although centred on ~65ºS, 140ºE, the exact location of the field experiment remains flexible, and will depend upon sea-ice conditions encountered at the time.

A key element of overall validation effort is the use of data collected at multiple scales as a means of extrapolating spatially and temporally limited *in situ* data to larger areas. Large-scale information on ice concentration/type will be provided by helicopter digital aerial photo transects. An aim is to use the helicopters to carry out random sampling of snowcover thickness over a number of pixels in a short time period. This depends on the occurrence of good flying conditions. One of the 2 helicopters will also carry an electromagnetic induction system designed to measure sea-ice thickness (and operated by Dr Christian Haas, Alfred-Wegener-Institut für Polarforschung, Germany), supplemented by a laser altimeter. A similar system will be operated from the boom on the ship to provide underway sea-ice thickness measurements.

Key sources of satellite validation data for AMSR-E ice products will include:

- Landsat-7, GLI, Ikonos/Quickbird, MODIS (high-resolution visible-thermal IR);
- AVHRR, OLS, AATSR, GLI, MODIS (medium-resolution visible-thermal IR);
- SAR (RADARSAT ScanSAR, Envisat ASAR) (high-resolution active microwave); and
- Radar Scatt (QuickSCAT).

These data will be obtained locally via the TERSS X-band receiving station in Hobart (Tasmania), onboard the ship via a newly-acquired SeaSpace TeraScan system, by the HRPT receiving station and by data requisitions via projects with ESA and NASDA as well as another project with NASA (re Radarsat data). Indeed, the success of the experiment depends on close coordination not only with the NASA AMSR-E validation framework but also with similar initiatives within ESA and NASDA.

The *in situ* measurement strategy is based on series of ice stations of various length, ranging from very short (30 minutes) through medium (4-5 hours) to long (3 days). Detailed *in situ* measurements will include i) snow thickness, characterization (density, grain size, wetness) and temperature; ii) ice thickness; iii) ice core characterization (grain size, temperature, snow-ice content); and iv) the distribution of flooding and snow-ice formation.

The *in situ* and helicopter observations will be supplemented by hourly ship observations of sea ice and snowcover thickness and characteristics using a standard observation protocol while the ship is in transit. In addition, ship's rail will be equipped with an array of remote sensing devices, including thermal IR radiometers, a time-lapse video camera and hopefully passive microwave radiometers operating at frequencies equivalent to those of the AMSR-E (please see *Issues* below).

Twice-daily aerosonde balloon launches will provide atmospheric profiles of atmospheric water vapour/moisture with which to derive corrections for atmospheric effects. Collaborative work with Dr Julienne Stroeve (NSIDC, University of Colorado) will also use radiative transfer modeling to combine sea ice and atmospheric components to simulate top-of-the-atmosphere (TOA) brightness temperatures at AMSR-E frequencies.

An array of buoys will be launched within the sampling grid to gain information on ice location/motion. Some will also be equipped with thermistor strings to provide information on the temporal variability of air and ice/snow temperature.

Data Management and Availability

Overall data management for the AMSR-E Validation Program will be coordinated through the responsible NASA official, Dr. Elena Lobl. Data sets will be made available and archived as soon calibration and quality control have taken place. It is anticipated that the data will be archived no later than approximately one year after the completion of the field campaign.

ISSUES

- Changes have been enforced by the lack of a fixed-wing aircraft campaign to overfly the field experiment (as originally proposed), with the aircraft campaign concentrating on a near-contemporaneous sea-ice experiment in West Antarctica (organised by Dr Joey Comiso, NASA GSFC). This already sets us apart from the other two sea-ice validation campaigns, and limits our ability to extrapolate the surface measurements to larger areas i.e. covering more AMSR-E pixels.

- An issue remains as to whether a ship-borne passive microwave radiometer operating at frequencies and polarizations equivalent to those of the AMSR-E sensor will be onboard. Negotiations are currently underway with Dr Karen St Germain of the US Navy NRL to this end. If we are unable to obtain a passive microwave radiometer, then we must forego the ability to obtain information about sea-ice emissivity and its variability as a function of ice type. The lack of an onboard radiometer would also negatively impact planned radiative transfer modeling activities.

- The acquisition of real-time satellite data, and its transmission to the ship in the field, is of key importance, as is the non-real time requisition of satellite data over the study region prior to, during and after the experiment. High-resolution Landsat 7 ETM and Ikonos/Quickbird are required. It would be highly desirable to acquire these data through the NASA AMSR-E validation project.

- The need to obtain sufficient observations with which to adequately validate the AMSR-E sea-ice products remains a major challenge, given the large pixel size of the latter, as does the need to resolve temporal variability between measurements (e.g. sea ice drift, changes in snowcover thickness due to precipitation etc.). This needs careful consideration in the time prior to the cruise. For example, we have worked out that 35-97 floes need to be measured to estimate the mean snow thickness to within 5 cm, given the large observed standard deviation on the large scale (measured on a 1999 cruise). Moreover, the measurements must take place within some time span when things are not changing too rapidly. With this in mind, the plan is to use helicopters to "hop" between floes to obtain quick snow thickness measurements. More input and guidance on this and other validation issues would be greatly appreciated, as we are fully aware of the need to collect sufficient data with which to satisfy the validation requirements.

- All experiments in Antarctic the sea-ice zone are at the mercy of the weather conditions, which are notoriously unpredictable and harsh. The helicopter aerial photo flights in particular are highly dependent on good conditions. It is envisaged that some of the 17 days will be lost due to poor weather and/or heavy ice conditions (which negatively impact the ship transit time).

FINAL COMMENT

Finally, we are very grateful to NASA for their excellent support, and look forward to developing a very close and amicable cooperative relationship with the AMSR-E validation team over the coming months.